Constellation X

The Constellation X-ray Observatory

TES Development at NIST for the XMS

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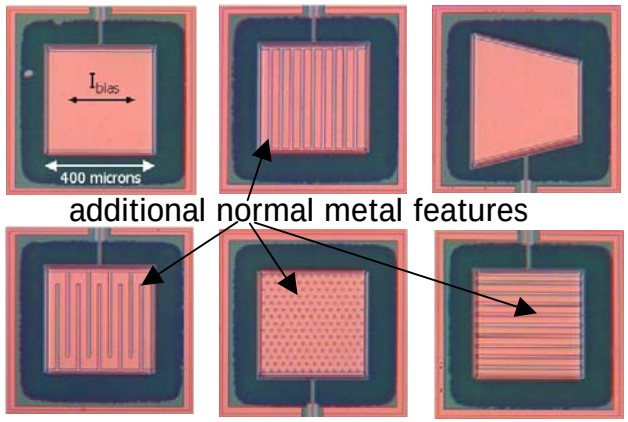
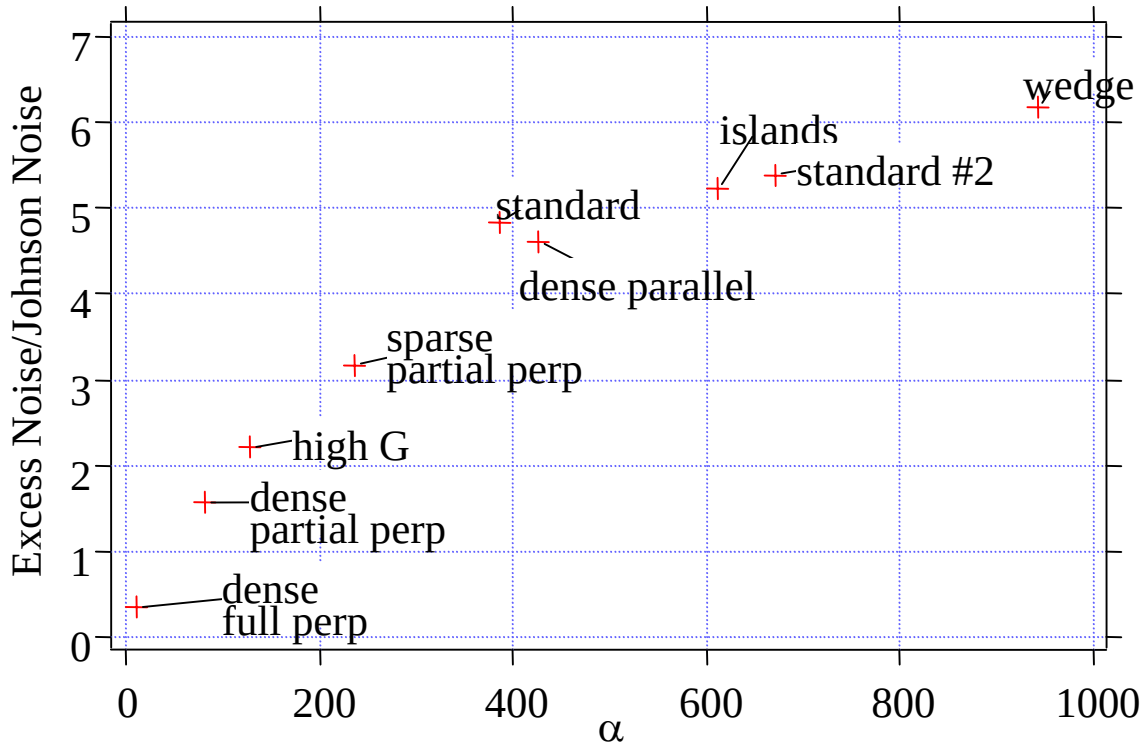
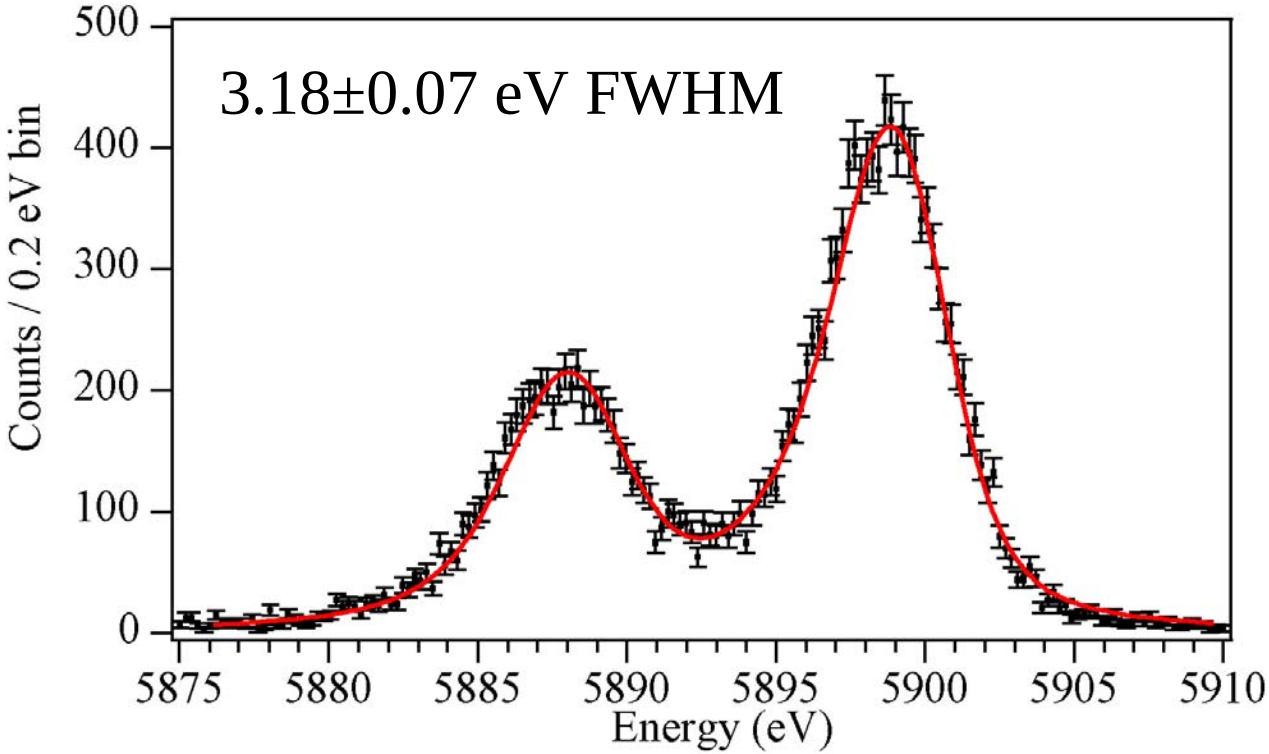
Excess noise in TES microcalorimeters

- The energy resolution of a TES x-ray microcalorimeter is limited by the excess noise.
- With Constellation-X funding, we have developed an empirical model of excess noise, leading to a breakthrough in resolution.



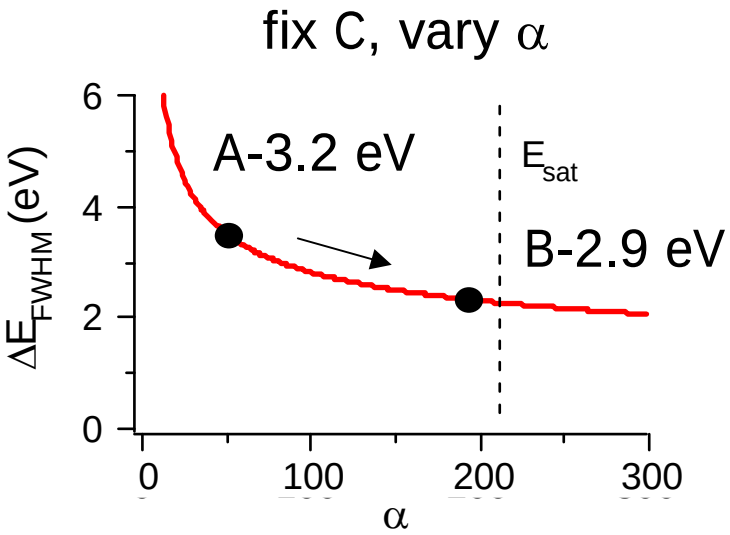


3 spectra: understanding & engineering the TES

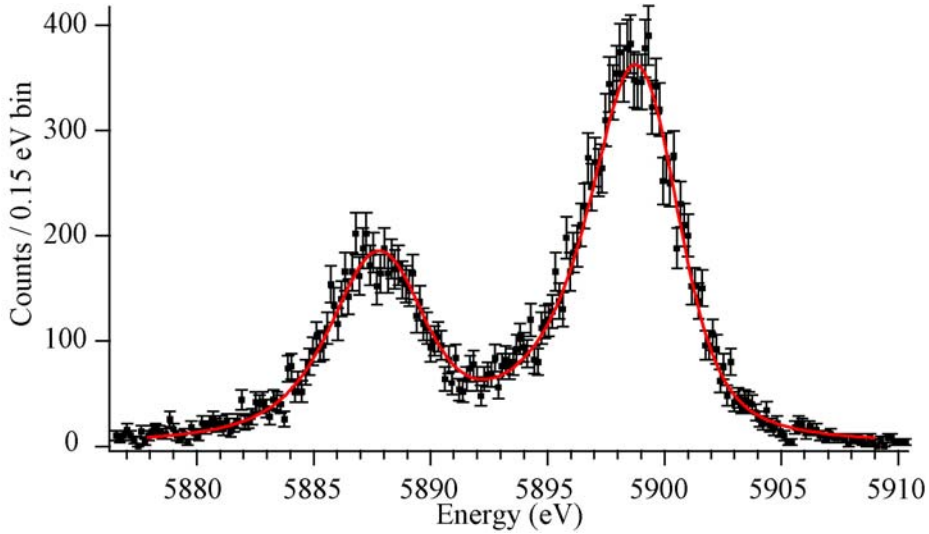


- Initial implementation of noise mitigation features improved our Fe-55 TES resolution to 3.18 eV FWHM
- Accurate characterization of the response of the microcalorimeter requires many thousands of counts.

Optimization #2



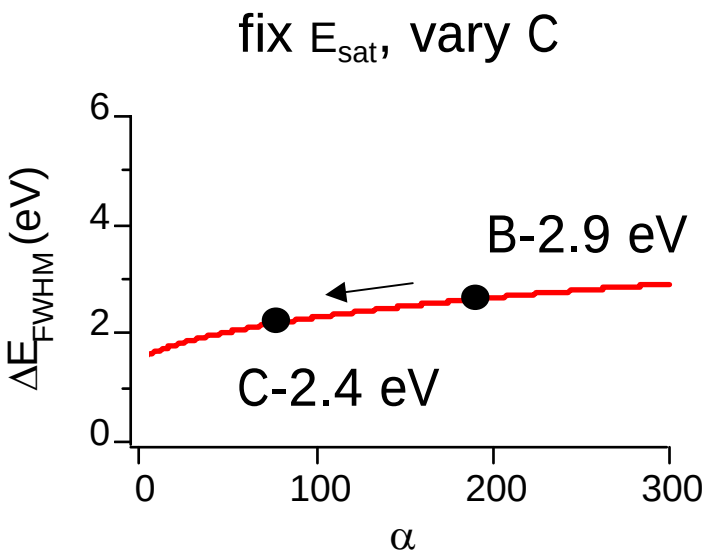
2.9±0.1 eV FWHM



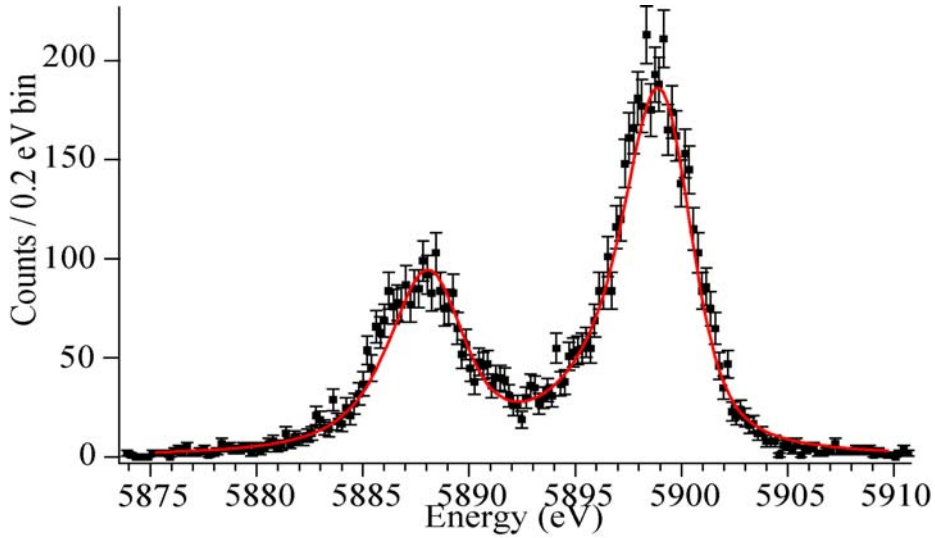
- Optimization of the α vs. excess noise (M) tradeoff in the TES design (with heat capacity C fixed) further improved spectral resolution from 3.2 eV to 2.9 eV

$$\Delta E_{FWHM} = \sqrt{\frac{k_B T_0^2 C}{\alpha}\sqrt{1+M^2}}$$

Optimization #3



2.37±0.11 eV FWHM

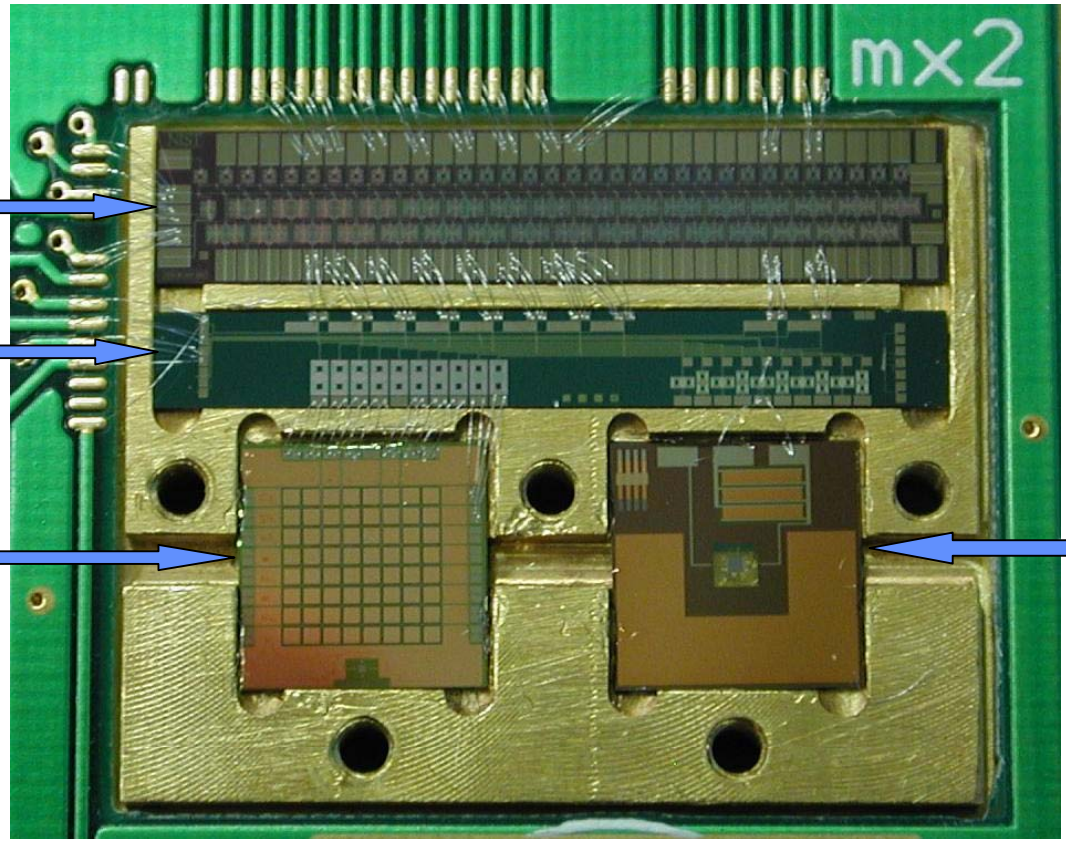


- Optimization of the heat capacity *C* (with saturation energy E_{sat} ~ C T/α fixed) further improved spectral resolution from 2.9 eV to 2.37 eV.
- The best energy resolution with a non-dispersive detector

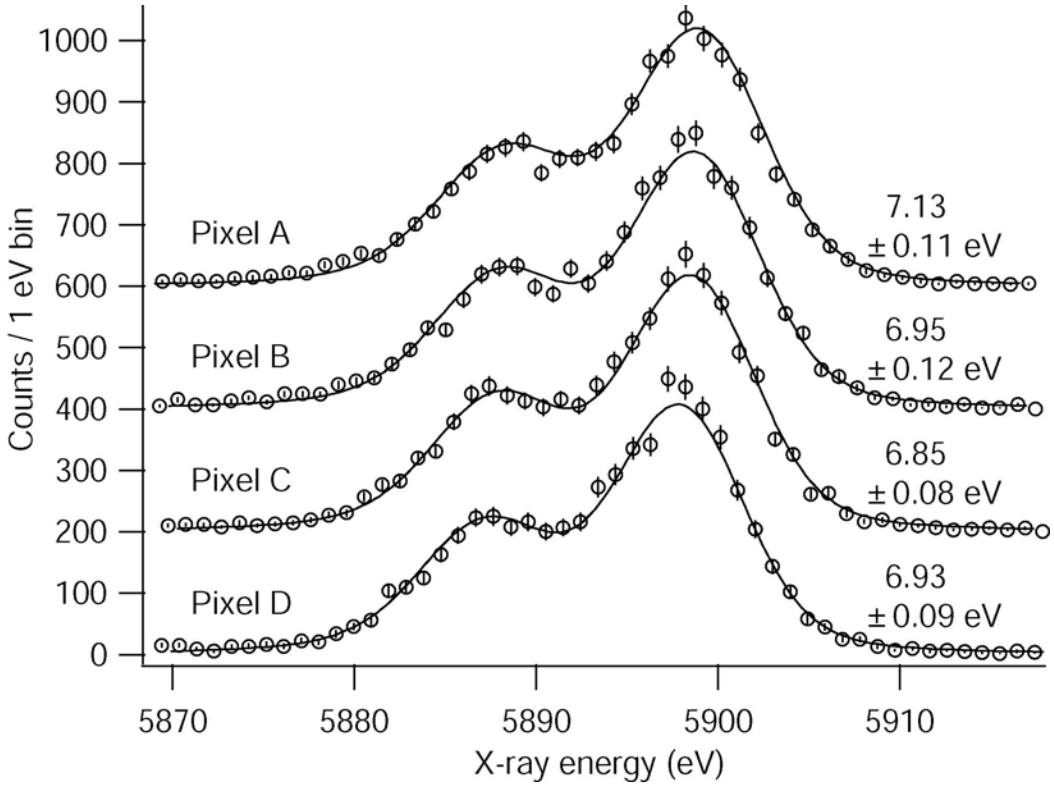
$$\Delta E_{FWHM} = \sqrt{\frac{k_B T_0^2 C}{\alpha}} \sqrt{1+M^2}$$

Cryogenic multiplexers

TES microcalorimeters have a pathway to large arrays due to their compatibility with cryogenic multiplexers. A cryogenic multiplexer technology is a must for a scalable Constellation-X calorimeter array.

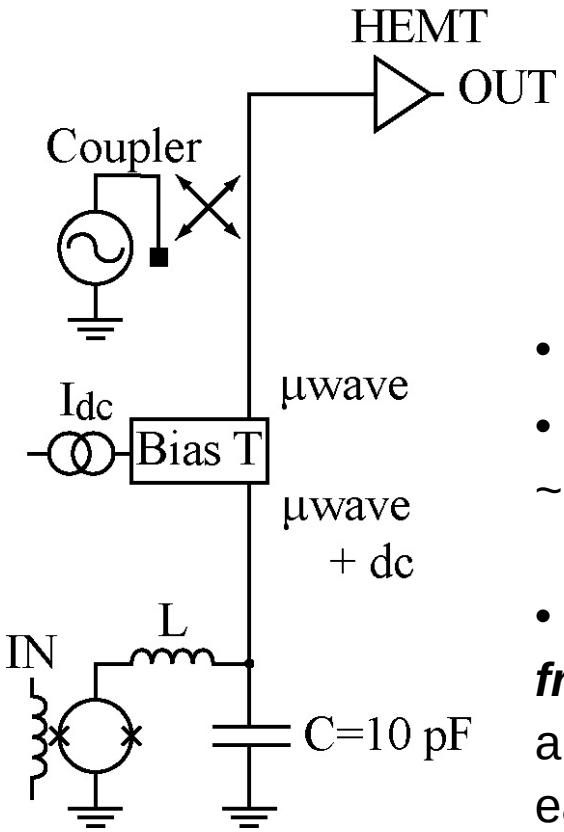


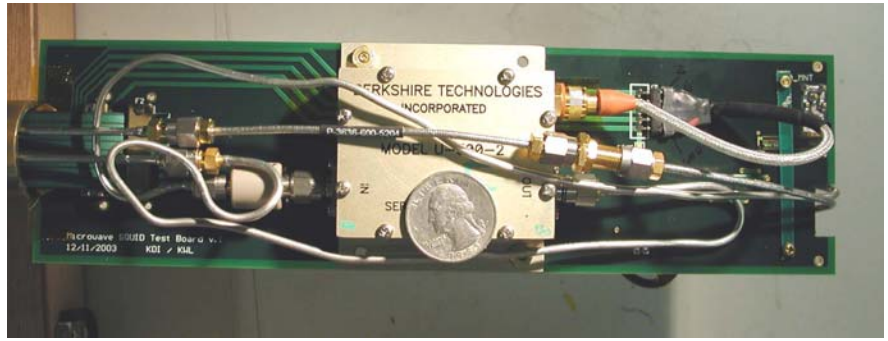
Demonstration: 4 pixels in one output column



- Spectra from 4 central pixels in array (no noise mitigation yet)
- Good uniformity
- Assisted in the development of models for multiplexing larger arrays

HEMT microwave reflectometer readout of 2nd-stage SQUIDs





- Excellent noise demonstrated: ~0.5 $\mu\Phi_0/\sqrt{Hz}$ at 4 K
- Significant increase in SQUID open-loop bandwidth to ~100 MHz

- 16 ***time-division multiplexed*** SQUID columns can be ***frequency-division multiplexed*** into one HEMT amplifier (potential of thousands of TES detectors in each HEMT).

- Analogous to TDMA cell phones